Establishing a Business Case for New Technologies

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Who are we?

- Organization: Research and Acquisition (ARA)
  - Mission
    - *"In a few words, we help the agency 'buy stuff well.' We buy quality products and services that are well researched and will be well used. We research and analyze FAA acquisitions so we buy quality products and services that are well-engineered, well-coordinated, cost-effective, valued by our customers and* ***deliver measurable benefits****…."* Charlie Keegan (ARA-1)

Outline

- Measuring Performance
- NAS metrics
- Safe flight 21 metrics
  - Safety and efficiency metrics
    - “The Effect of Reduced Unimpeded Taxi-Out Times on Departure Delays at Capacity-Constrained Airports”

Measuring Performance

- Identify set of metrics that are important for
  - Benchmarking
  - Measuring operational capacity and efficiency impacts of Operational Evolution Plan (OEP).
    - OEP is FAA's and aviation industry's implementation plan for capacity and efficiency improvements needed for National Airspace System (NAS) to meet future air traffic demand.

Proposed Air Traffic Organization Metrics

Aviation Industry Trends

Average daily flights

Passengers and cargo volume

Safety

- Accident rate
- Operational error rate
- Operational deviation rate
- Runway incursion rate

Financial

- Cost per flight
  - Total cost per employee
  - Dollars invested
  - AT cost per flight

Operations

Percentage of on time flights

Average delay for all flights

Ground stop minutes

Ground delay program minutes

Delays due to outage/Total system availability

Average delay arrival capacity

Airport arrival efficiency rate

Measuring Customer Objectives

Accessibility (Capacity and Throughput)

- Focus on period of peak demand
- Direct relation to delay

Predictability

- Variances associated with various capacity/throughput metrics

Efficiency

- Flight time by phase of flight
- Fuel burn

Flexibility

- Ability to meet users' ever-changing demands

Safety

Financial

Environmental Impact

- Noise level

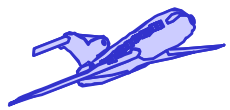
Metrics Used in SF21 Benefit Assessments

- Safety
  - Controlled flight into terrain (CFIT)
  - Other weather-related accidents
  - Runway incursion accidents
- Efficiency
  - Airport capacity increase
  - Arrival delay reduction
  - Reduction in taxi times

“The Effect of Reduced Unimpeded Taxi-Out Times on Departure Delays at Capacity-Constrained Airports”

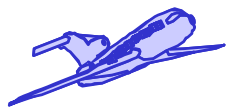
- Will reducing the time it takes an aircraft to taxi-out from gate to the runway reduce departure delays when a queue exists?

Taxi-Out Overview



- Taxi-out phase can be broken into two stages.
  - Pushback from gate to runway or departure queue
  - Runway or departure queue to lift-off
- Inefficiencies exist within both stages.
  - Pilot unfamiliarity with taxi route
  - Navigation with reduced visibility
  - Night
- Unimpeded taxi-out time defined as taxi-out time when no conflicting traffic is present.
  - Not minimum or optimal time
  - Can be reduced as pilot skills are enhanced

Safe Flight 21 Program



- Pilots have option to equip aircraft with cockpit tools that enhance their abilities to taxi from the gate to the runway or departure queue.

- Moving map display of the airport surface
  - Highly accurate own-ship position
  - Comprehensive digital map of the airport surface
    - Includes runways, taxiways, holding areas, ramps, hangars, and prominent structures.

- Monitor progress using the cockpit display and correlate position by reference to outside visual cues.

- Other traffic (aircraft and vehicles) displayed.

Problem Description

- Expect reduced unimpeded taxi-out times.

  1) No queue of aircraft waiting at runway

     Actual taxi-out time = unimpeded time

     $\Rightarrow$ Time savings realized

  2) Traffic exists and aircraft must yield or wait

     Actual taxi-out time > unimpeded time

     - Will time savings realized?
     - What if only subset of aircraft equipped with enhancement?

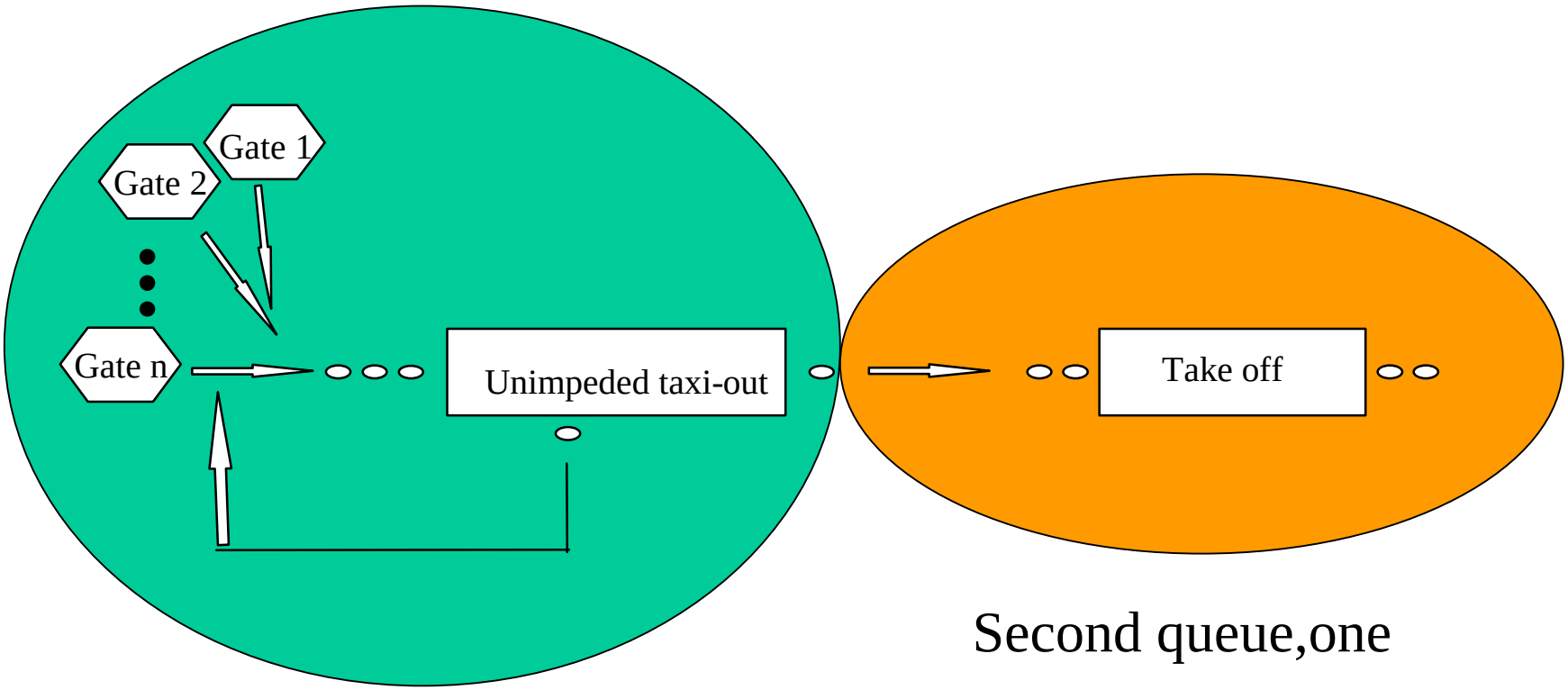
General Model

- Single runway configuration reduces taxi-out process to tandem or series queue.

- First station starts at gate and ends when aircraft enters departure queue.
  - General distributions used to represent interarrival service times.
  - Maximum number of aircraft that can simultaneously taxi-out without adding additional delays considered.

- Second service station consists of single runway.
  - Arrivals into second station are aircraft exiting first station.
  - Service time in this station consists of aircraft take-off.

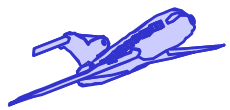
Series Queue



First queue, multiple servers

Second queue,one server

General Model (Cont.)



- Waiting area assumed infinite and aircraft wait at runway.
  - In reality, aircraft may hold at gate rather than wait at runway.
  - However, overall wait is unchanged using the simplifying assumption.

- When more than one runway exist, can segment system into several tandem queues and analysis still applies.

Heavy Traffic Scenario

- Under heavy traffic, aircraft depart gates and enter runway queue at rate close to, but not exceeding, runway capacity.
- Using equilibrium queueing theory, average wait time in queue can be explicitly calculated if following parameters are known.
  - Arrival rate
    - Average number of aircraft arriving to the runway queue during unit of time
  - Service rate
    - Average capacity during unit of time
  - Variance of interarrival time
    - Interarrival time is time between arrivals to runway queue.
    - Variance can further be approximated by variance of unimpeded taxi-out times.
  - Variance of service time
    - Take-off time

Heavy Traffic Scenario (Cont.)

- Arrival rate into departure queue
  - Same as rate at which aircraft depart gates.
  - Independent of unimpeded taxi-out time.

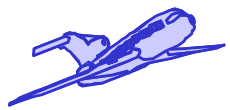
- Service time is take-off or runway occupancy time and is also independent of unimpeded taxi-out time.

- Variance of interarrival times into departure queue is only parameter to influence wait in queue.
  - If variance unchanged, then average wait in departure queue remains same and time savings realized.
  - If variance decreases, then average wait decreases further reducing total taxi-out time.
  - If variance increases, then average wait increases, offsetting reduction in unimpeded taxi-out times.

Special Case

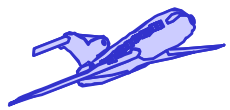
- Changes to unimpeded taxi-out distribution have no effects on waiting time in the second station when
  - Aircraft push back is Poisson process.
  - Unimpeded taxi-out time is exponentially distributed.
  - No feedback or returning of aircraft back to gate allowed
- Arrival into the second queue Poisson with same distribution by which aircraft enter first queue (pushback).
- Overall time in system reduced by reduction in unimpeded taxi-out time.

Mixed Equipage



- If equipage less than 100%, then unimpeded taxi-out time has mixed distribution.
  - Mean is weighted average of means for equipped and unequipped populations.
  - Variance equals weighted average of variances for equipped and unequipped populations plus positive term accounting for change in unimpeded taxi-out time.

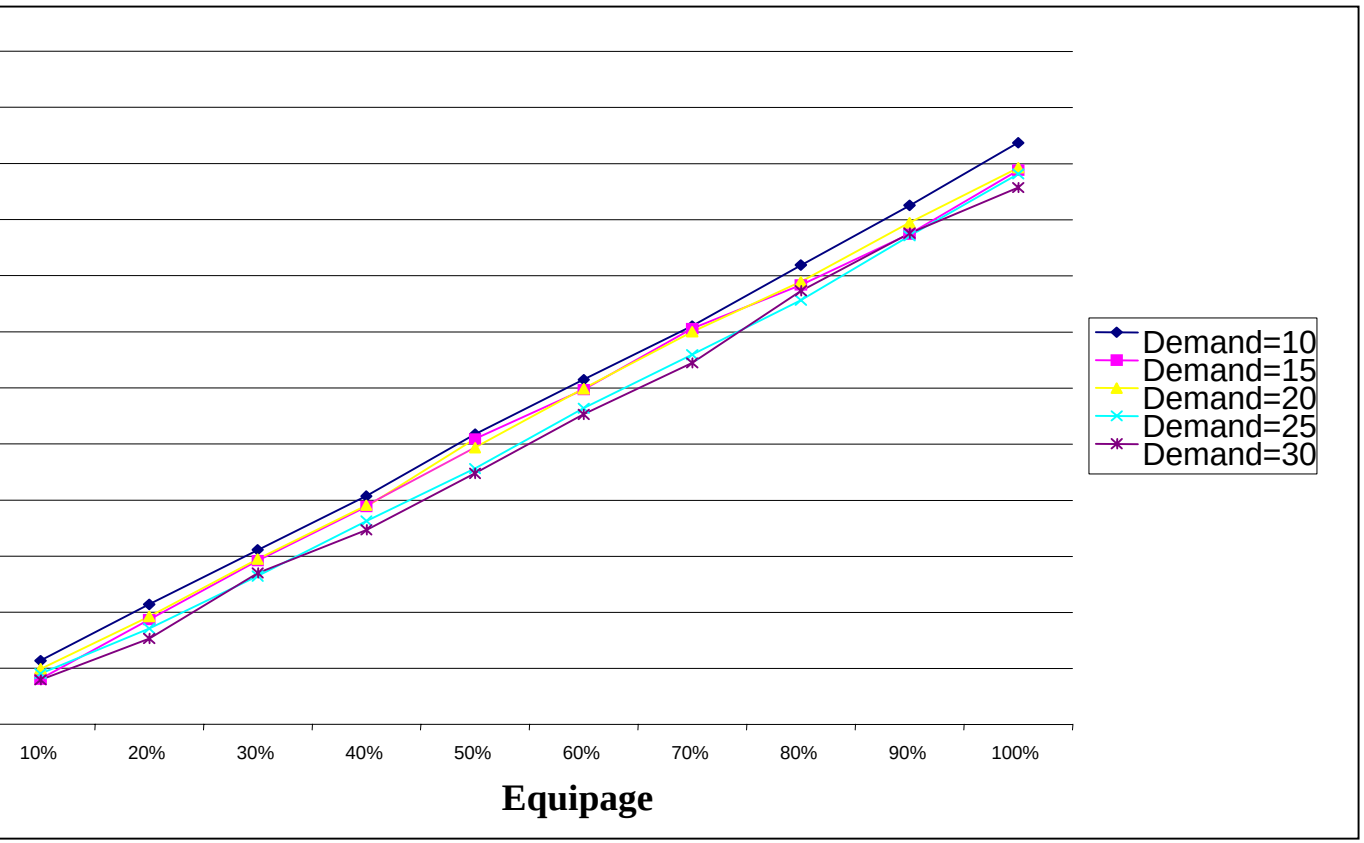
Discrete Event Simulation



- 150 scenarios
  - Capacity = 32 departures per hour.
  - Demand = 10, 15, 20, 25, and 30 aircraft per hour.
  - Baseline time from gate to runway queue = 10 minutes.
  - Unimpeded taxi-out time reduction
    - Mean times reduced by .25, .50, and 1.00 minutes.
    - Variance not changed.
  - Equipage = 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%

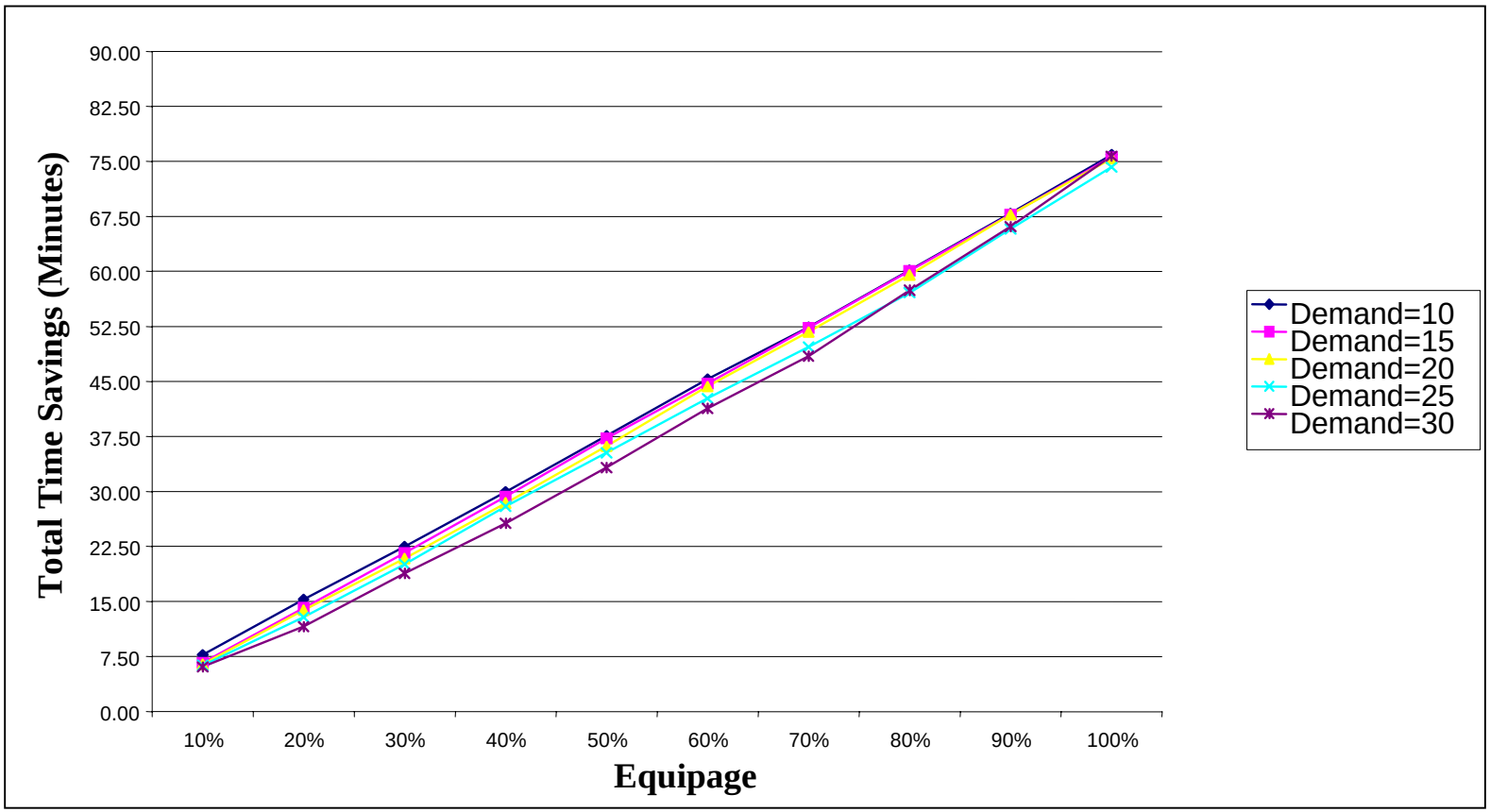
- Savings estimated for 150 aircraft.

Discrete Event Simulation (Cont.)



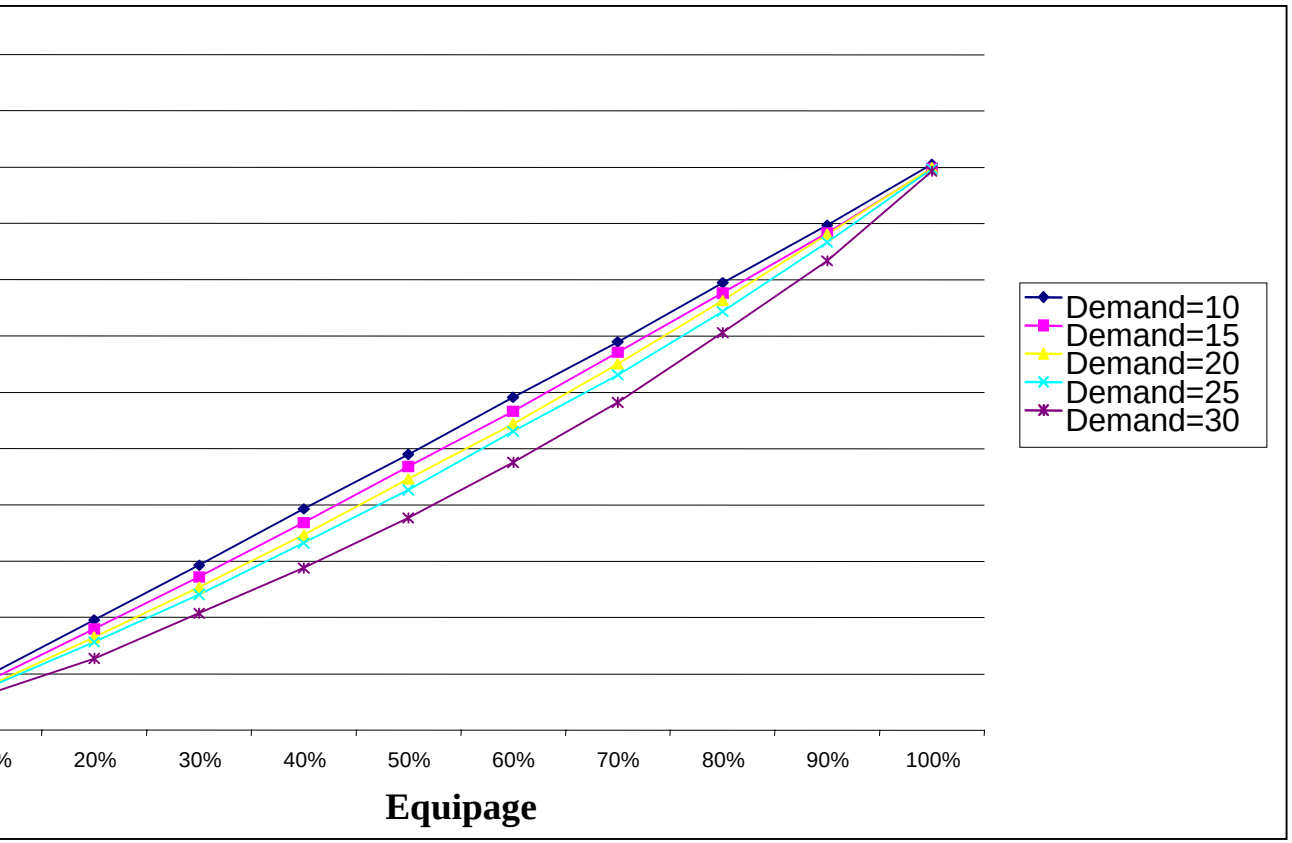
.25 Minute Reduction

Discrete Event Simulation (Cont.)



.50 Minute Reduction

Discrete Event Simulation (Cont.)



1.00 Minute Reduction

Summary

- Goal: Deliver measurable benefits.
- Identified some relevant metrics used in assessing Safe flight 21 benefits.
- Focused on reduced unimpeded taxi times reduction and capacity-constrained airports.
  - Departure delays can be reduced by improving pilots' abilities to navigate from gate to runway.
    - At capacity-constrained airports with departure queues.
    - With less than 100% equipage